

Interaction of Nitrogen and Flue Gas Desulfurization Sulfur for Production of Corn

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ABSTRACT

Nitrogen deficiency in soil often limits corn (*Zea mays* L.) growth, thus requiring fertilizer N inputs to achieve optimum yields. Nitrogen fertilizer is becoming more expensive and methods are needed to improve N use efficiency. Sulfur deficiency in several crops, including corn, has recently been observed in Ohio. However, little information is available related to the interaction of N and S fertilizers to affect the production of corn. Field experiments were conducted on a silt loam soil at Wooster, Ohio from 2002 to 2005 to test corn responses to the addition of N (seven rates from 0 to 233 kg ha⁻¹) as NH₄NO₃ and S (two rates of 0 and 33 kg ha⁻¹) from flue gas desulfurization (FGD) products. Corn grain yields, averaged over 4 years, were increased 7.0% when S was applied. This increase was statistically significant ($P \leq 0.05$). A statistically significant interaction effect of N by S was observed in 2004 and 2005 with the low N rates from 0 to 133 kg ha⁻¹ responding better to S than the high N rates. The highest grain yields were reached at the 133 kg N ha⁻¹ application rate with S addition. This suggests that S application can improve N use efficiency and decrease the amount of N required for optimum corn production. Reduced N fertilizer application rates reduce input costs and can also help maintain good water quality. Nitrogen, P, K, Mg and S in corn grain were slightly increased by application of 33 kg ha⁻¹ of S when N was applied at rates of 100 and 200 kg ha⁻¹. These results indicate application of N fertilizer with S promoted uptake, by corn plants, of N and other major plant nutrients.

INTRODUCTION

Nitrogen is a key nutrient limiting yields of corn. Economically optimal N fertilizer rate varies among fields and is influenced by a number of factors including soil conditions. Sulfur is also an essential element for higher plants. In recent years, deficiencies of S in crops have increased worldwide. Plant requirement for S is closely related to N nutrition. Flue gas desulfurization (FGD) products are created when coal is burned and SO₂ is removed from the flue gas. The FGD products contain sulfates, especially gypsum (CaSO₄·2H₂O), which is an excellent source of S for corn. The objectives of this study were to evaluate FGD products as S fertilizers and to assess the interaction of N and S fertilizer addition on the yield and element composition of corn grain and plant available nutrients in soil.

MATERIALS AND METHODS

For four consecutive years (from 2002 to 2005), field experiments for corn production were conducted on an agricultural soil (Wooster silt loam, Oxyaquic Fragiudalf) near Wooster, Ohio. Before treatments were applied, soil samples (0–20 cm) were collected and analyzed as described in Sparks et al. (1996) to determine fertility status (Table 1). Two sources of S fertilizer (FGD-product and FGD-gypsum) were used in this study. Some selected properties of these materials are reported in Table 2.

Table 1. Selected characteristics of the Wooster silt loam soil (0–20 cm depth) from 2002–2005 corn fields before application of N and S fertilizers.

Year	pH	Exchangeable Cations					CEC ¹ cmol kg ⁻¹	Available SO ₄ -S ² mg kg ⁻¹	Organic Matter ³ g kg ⁻¹
		P	K	Ca	Mg	Na			
		mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹			
2002–2003	6.8	27.0	125	1050	208	7.4	33.9	25.2	
2004–2005	6.9	29.9	102	1170	245	8.1	46.7	30.1	

¹Cation exchange capacity

Nitrogen fertilizer (NH₄NO₃) was applied at rates of 0, 67, 100, 133, 167, 200 and 233 kg N ha⁻¹ and S fertilizer (FGD-product in 2002 or FGD-gypsum in 2003, 2004 and 2005) was applied at rates of 0 and 33 kg S ha⁻¹. The experimental design was a split-plot in a randomized complete block with four replicates.

Table 2. Concentrations of major and trace elements in the flue gas desulfurization (FGD) product and FGD-gypsum.

Element	FGD product ¹	FGD-gypsum ²
Major element mg kg ⁻¹		
Al	19.6	0.228
Si	260	213
Ca	27.1	8.112
S	67.1	164
Fe	16.5	0.222
Trace element mg kg ⁻¹		
As	118	<11
B	194	5.8
Br	122	8.5
Cl	<0.12	<0.1
Cr	127	<1.0
Cu	1.57	<0.9
Mn	362	1.3
Na	12.2	<0.9
Ni	72.4	<0.9
Pb	129	<0.9
Se	<0.6	<25.0
Zn	33.2	4.9

¹FGD product was from Norbent Technologies Corporation (Chen et al., 2005) and FGD-gypsum was from Cinergy Corporation.

RESULTS

Grain Yield

Nitrogen and S effects on the yields of corn at Wooster, Ohio for individual years from 2002 to 2005 are presented in Fig. 1 and Table 3. Four year corn yield averages from 2002 to 2005 are presented in Fig. 2 and show that the maximum yield was reached at the rate of 167 kg N ha⁻¹ when 33 kg S ha⁻¹ was applied and at the rate of 233 kg N ha⁻¹ when no S was applied. There was an interaction of N x S on corn yield in 2004 and 2005 with the low N rates (0 to 167 kg N ha⁻¹) responding better to the S additions than the higher N rates

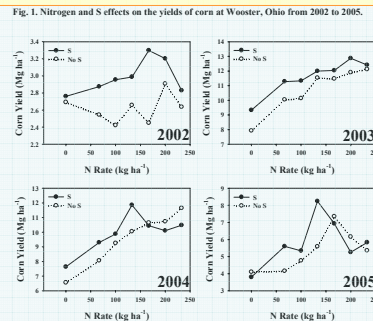


Fig. 2. Average corn yields from 2002 to 2005 as affected by application of N and S fertilizers.

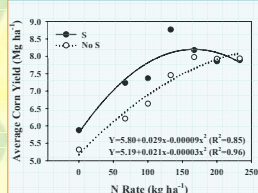


Table 3. Mean concentrations in 2002 and 2003 of major elements in corn grain harvested from plots treated with N fertilizer and flue gas desulfurization (FGD) product or FGD-gypsum.

N Rate	S	P	K	Ca	Mg	S
mg kg ⁻¹						
2002						
N Rate						
0	16.1	2.39	2.82 a ¹	0.851	1.09	1.84
100	16.8	2.41	2.83 a	0.840	1.10	1.85
133	16.5	2.28	2.80 a	0.840	1.07	1.87
167	16.5	2.28	2.80 a	0.840	1.07	1.87
200	16.5	2.28	2.80 a	0.840	1.07	1.87
233	16.5	2.28	2.80 a	0.840	1.07	1.87
2003						
N Rate						
0	16.6	2.37	2.78	0.845	1.10	1.85
133	16.3	2.34	2.79	0.848	1.07	1.85
167	16.3	2.34	2.79	0.848	1.07	1.85
200	16.3	2.34	2.79	0.848	1.07	1.85
233	16.3	2.34	2.79	0.848	1.07	1.85

N Rate	S	P	K	Ca	Mg	S
mg kg ⁻¹						
2004						
N Rate						
0	12.3	2.56	3.24 a	0.850 b	1.02	0.90
100	12.7	2.44	2.90 b	0.851 b	0.96	0.92
133	12.3	2.45	2.90 b	0.851 b	0.97	0.96
167	12.7	2.45	2.90 b	0.851 b	0.97	0.96
200	12.7	2.45	2.90 b	0.851 b	0.97	0.96
233	12.7	2.45	2.90 b	0.851 b	0.97	0.96
2005						
N Rate						
0	13.1 a	2.39 b	2.99 b	0.868	0.95 b	0.92
133	12.4 a	2.58 a	3.16 a	0.868	1.02 a	0.93
167	12.5	2.58	3.16	0.868	1.02	0.93
200	12.5	2.58	3.16	0.868	1.02	0.93
233	12.5	2.58	3.16	0.868	1.02	0.93

¹Different letters in the same column within an area represent a significant difference at P=0.05.

Grain Elements and Selected Available Nutrients in Soil

Concentrations of N, S, and other major plant essential elements in the corn grain in 2002 and 2003 are presented in Table 4. In 2002, application of N fertilizer slightly increased Ca, N and S concentrations and decreased K concentration in corn grain. In 2003, concentrations of P, K, and Mg were also increased and concentrations of N decreased by application of S fertilizer. The concentrations of all the other elements, including S, were not affected by the application of N and S fertilizers.

Mean concentrations of selected plant essential elements in Mehlich-III extracts obtained from the 0–30 cm soil layer in 2003 and 2005 are presented in Table 5. In 2003, application of N fertilizer increased soluble S from 61 to 88 mg kg⁻¹ and Zn from 2.5 to 4.2 mg kg⁻¹ in the soil. Application of S fertilizer increased soluble Cu from 4.2 to 4.6 mg kg⁻¹. In 2005, application of N fertilizer increased available B from 1.26 to 1.30 mg kg⁻¹. Application of S fertilizer increased available S from 50 to 58 mg kg⁻¹ and K from 113 to 141 mg kg⁻¹. All the other element were not changed by N or S fertilizer application, and data were not shown.

CONCLUSIONS

The experimental sites were clearly deficient in S for corn. During the four-year experiment, corn yield averages were significantly ($P \leq 0.05$) increased 7.0% from 7.1 to 7.6 Mg ha⁻¹ by application of 33 kg S ha⁻¹. When S was applied, the highest yields were reached with a lower N application rate. An interaction of N x S was observed with the low N rates (0 to 167 kg N ha⁻¹) responding better to the S additions than the higher N rates. This suggests that the efficiency of fertilizer N use can be improved by adding S with N fertilizer when growing corn.

REFERENCES

- Chen, L., W. A. Dick, and S. Nelson. 2005. Flue gas desulfurization products as sulfur sources for alfalfa and soybean. Agron. J. 97:265–271.
- Mehlich, A. 1984. Mehlich III soil test extract: A modification of Mehlich II extract. Commun. Soil Sci. Plant Anal. 15: 1409–1419.
- Sparks, D.L., A.L. Page, P.A. Helmke, R.H. Loeppert, P.N. Sotgiu, M.A. Tabatabaie, C.T. Johnston, and M.E. Sumner. (ed) 1996. Methods of soil analysis, Part 1: Chemical methods. SSSA Book S. 5. SSSA and ASA, Madison, WI.